STATE OF WASHINGTON
DEPARTMENT OF COMMUNITY,
TRADE AND ECONOMIC DEVELOPMENT

Washington State's Greenhouse Gas Emissions: Sources and Trends

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Summary

This paper reviews the sources of greenhouse gas emissions from Washington, their historical trends, and is an update of a 1999 report by the same title[1]. Carbon dioxide (CO_2) is the dominant greenhouse gas emitted by human activity in Washington, representing 85 percent of total emissions in 2000. Other important greenhouse gases examined in this report include methane (CH_4), nitrous oxide (N_2O), and perfluorocarbons (PFC).

Total greenhouse gas emissions increased from 99.5 million tons[2] in 1990 to 109.3 million tons in 2000: an increase of about 1 percent per year. Energy related activities were responsible for 92.5 million tons, about 85 percent of total greenhouse gas emissions in 2000. Carbon dioxide emissions within the energy related category were 86.5 million tons in 2000, and are the dominant source of greenhouse gas in Washington - 79 percent of total greenhouse gas emissions. This report focuses on direct carbon dioxide emissions from the energy related activities.

The transportation sub-sector is the primary source of energy related carbon dioxide emissions. In 2000, transportation sector carbon dioxide emissions were 48.8 million tons, or 56.4 percent of energy related emissions. Within the transportation sector use of motor gasoline (51 percent), diesel (16 percent), and jet fuel (22 percent) were the main sources of carbon dioxide emissions.

Because of our abundant hydropower, carbon dioxide emissions from electricity generation were quite low in Washington until 1972 when the coal-fired Centralia generation station came on-line. Carbon dioxide emissions associated with electricity generation have risen slowly ever since 1972 and in 2000 were 15.8 million tons: 18 percent of energy related emissions.

The report examines several emission trends. Annual emissions of carbon dioxide per capita in Washington, after declining in the late 1970s and early 1980s because of government regulations and increasing energy prices, have remained relatively constant over the last 20 years at 13-15 tons per person. Annual emissions of carbon dioxide per constant dollar of gross state product have declined by 45 percent over the past 25 years as businesses have diversified and become more efficient. Despite continuing efficiency improvements, total energy related carbon dioxide emissions for Washington continue to increase. This increase is statistically highly correlated with state population growth.

[1] Available at http://www.cted.wa.gov/energy/archive/papers/wa-ghg99.htm

[2] Because the various greenhouse gases have different global warming potential they are expressed as CO_2 equivalent emissions.

Washington's Greenhouse Gas Emissions: Sources and Trends

Overview

Global greenhouse gas (GHG) concentrations continue to increase and many nations around the world are taking actions to reduce their emissions of GHGs. Washington State has joined with Oregon and California in an effort to explore means of reducing emissions as part of the West Coast States Governors' Global Warming Initiative. This paper reviews the sources of greenhouse gas emissions from Washington and their historical trends and is an update of the 1999 report *Greenhouse Gas Emissions in Washington State: Sources and Trends*.[1]

The principal greenhouse gases emitted from activities in Washington include, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and perfluorocarbons (PFC). There are several sources for most of these gases and they are shown in Table 1. For example, fossil fuel combustion produces mainly CO_2, but CH_4 and N_2O are also produced, in significant quantities by internal combustion engines. In the agricultural sector, manure decomposition produces both CH_4 and N_2O. The emissions are categorized into three major sectors; energy, industrial processes, and agriculture.

Table 1. Major Sources of Greenhouse Gas Emissions in Washington

Sector	Activity	CO_2	CH_4	N_2O	PFC
Energy	Fossil fuel combustion	**X**	**X**	**X**	
	Coal mining & NG Distribution		**X**		
Industrial	Cement & Lime	**X**			
	Aluminum	**X**			**X**
	Solid waste/landfill	**X**	**X**	**X**	
Agriculture	Enteric Fermentation		**X**		
	Manure management		**X**	**X**	
	Soil Fertilizer			**X**	
Global Warming Potential (GWP)		1	23	296	7,235

Greenhouse gases differ in their impact on global warming. For example, one pound of nitrous oxide is 296 times more potent than a pound of carbon dioxide in affecting global warming. This means that emissions of relatively small quantities of gases like nitrous oxide can have significant impacts on global warming potential. Table 1 shows the global warming potential (GWP) values for the various gases taken from the IPCC Third Assessment Report[2].

Emissions were calculated using the *State Tool for Greenhouse Gas Inventory Development*, a series of worksheets developed by the Environmental Protection Agency[3]. The worksheets use the most recent information on data sources, emission factors, and methods that are consistent with the *Intergovernmental Panel on Climate Change Good Practice* Guidance[4]. The emissions are given in million tons of carbon dioxide equivalent to permit easy comparisons of their impact on global climate change.

Figure 1 shows the contributions from the different sectors and gases for the years 1990, 1995 and 2000. Energy related emissions are the dominant source of greenhouse gas emissions and have increased from 80.5 million tons CO_2-equivalent in 1990 to 92.5 in 2000, an increase from 80 percent of total emissions to 85 percent over the past decade. Carbon dioxide is the dominant greenhouse gas followed by methane, nitrous oxide, and perfluorocarbons

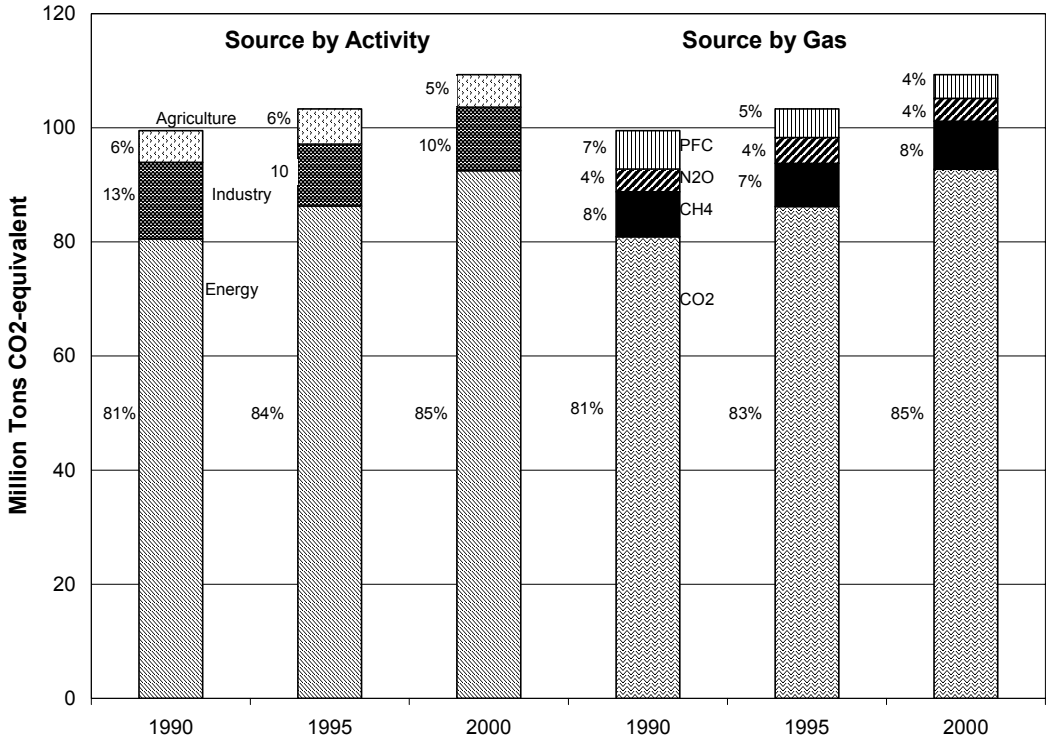

Figure 1. Greenhouse Emissions by Sector and Gas Type

Non-energy industrial sector greenhouse gas emissions have declined primarily due to reduced emissions from aluminum production. This reduction is the result of two factors, process changes that reduced CO_2 and PFC emissions per ton of aluminum produced, and the post-2000 decline in aluminum production rates. Non-energy agricultural sector greenhouse emissions have remained relatively constant but their percentage contribution has declined as total emissions have increased. The rest of this paper will only examine energy-related carbon dioxide emissions, as they are the dominant source of greenhouse gas emissions in the State of Washington.

Energy –Related Greenhouse Gas Emissions

Figure 2 shows the *direct* carbon dioxide emissions from the combustion of fossil fuels in the buildings, industrial, transportation, and electric power sectors from 1960 to 2002. Emissions for 2001 and 2002 are preliminary values and should be viewed as such.

The buildings sector includes both the residential and commercial sectors. Emissions linked to the use of electricity by the building, industrial, and transportation sectors are not included in this discussion on direct emissions. We will discuss the importance of emissions associated with electric power generation later on in this paper.

1. Buildings and Industrial Sector

Some obvious trends and changes are apparent. Emissions from the direct use of fossil fuels in the building and industrial sectors have been relatively constant over the past 40 years, even though the use of energy in these sectors has increased. Two factors have allowed the phenomena of increased energy usage and constant greenhouse gas emissions. First, there has been fuel switching from coal and petroleum fuels to natural gas. Since natural gas emits fewer pounds of carbon dioxide per Million Btu than coal or petroleum fuels, fuel switching has moderated carbon dioxide emissions. The second factor is the increasing efficiency with which energy is utilized in the industrial and building sectors.

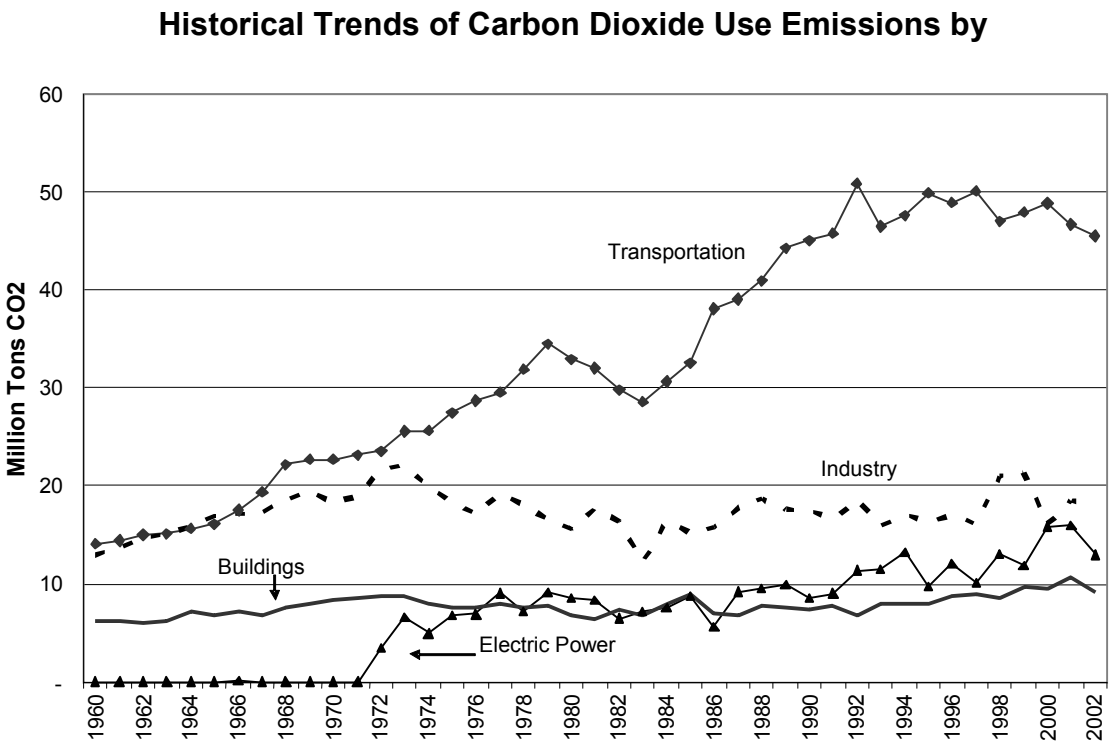

Figure 2. Historical Trends of Carbon Dioxide Direct Use Emissions by Sector
* Note: Buildings sector includes both commercial and residential sectors.

2. Transportation sector

The other obvious characteristic of Washington's energy related carbon dioxide emissions shown in Figure 2 is the dominant role played by the transportation sector, which includes emissions from highway and non-highway vehicles, trains, planes and ships. In 1960, transportation accounted for 42 percent of energy related carbon dioxide emissions. The percentage increased to 52 percent by 1980, and has remained relatively constant, with a slight increase in emissions in the early 1990s[3]. Of course, the transportation percentage share of CO_2 emissions is also influenced by emission increases or decreases in the other sectors.

Motor gasoline (51%), diesel (16%) and jet fuel (22%) use dominate CO_2 emissions within the transportation sector, accounting for 90 percent of this sector's emission in the year 2000. While absolute CO_2 emission have increased for the transportation sector, the share of CO_2 emissions within this sector corresponding to motor gasoline use actually declined from 65 percent in 1972 to about 45 percent in the early 1990s. The cause of

3. The transportation sector includes residual and bunker fuel used by large ships. This category varies significantly on a year-to-year basis: reported CO_2 emissions in 1984 associated with residual transportation fuel combustion were 0.9 million tons, while in 1992 reported emissions were 12 million tons. This large variance means trend analysis in the transportation sector must be undertaken with care.

this decline was the rise in federal vehicle fuel efficiency standards for cars and trucks during the 1970s through late 1980s. The decline in percent of emissions associated with motor gas usage occurred despite significant increases in the number of vehicles and total vehicle miles traveled. Since the early 1990s the percent of emissions associated with motor gas usage has steadily increased, as federal fuel economy standards have remained the same for nearly fifteen years. In addition, consumers have increasingly switched to trucks and sports utility vehicles, which are significantly less fuel efficient than cars. Figure 3 below illustrates the increase in vehicle miles traveled and vehicle fuel economy from the 1970s to the mid 1990s.

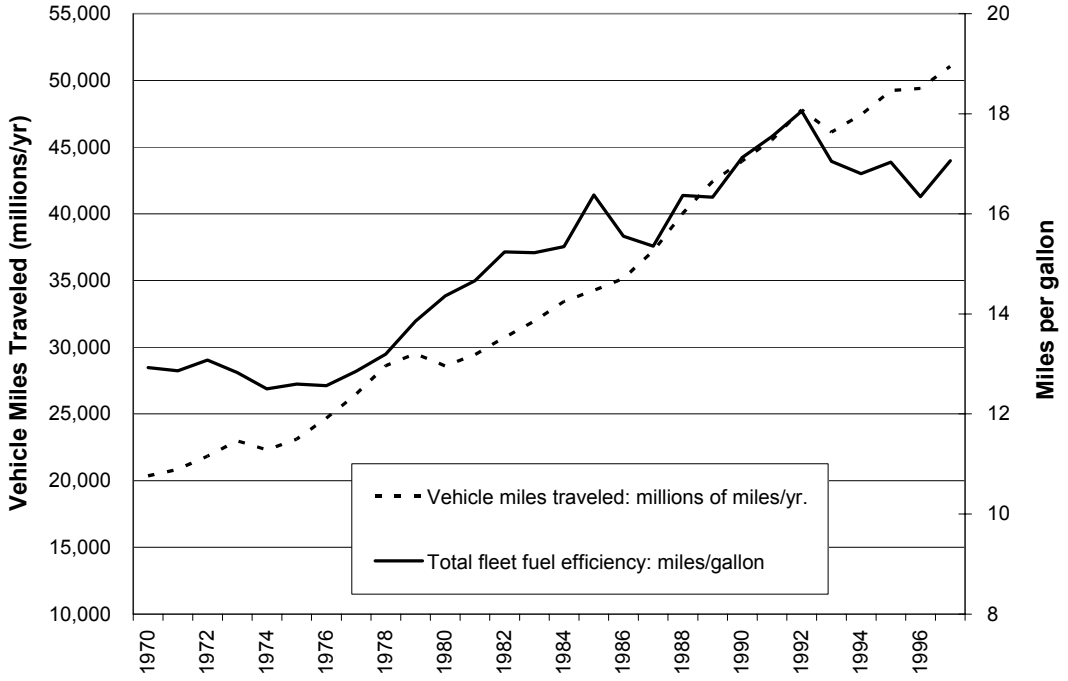

Figure: 3 Trends in Total Vehicle Miles Traveled and Vehicle Fuel Efficiency for Washington State.
Source: Federal Highway Statistics

3. Electric power sector

Carbon dioxide emissions from electric power generation are quite different from the other sectors. Up until 1972, there were essentially no carbon dioxide emissions, as electric power was generated almost entirely by hydropower. When the coal fired Centralia power plant came on line there was an obvious and dramatic increase in emissions. Emissions stayed relatively constant until the late 80's when natural gas began to be used for electrical generation and the emissions increased. Over the last five years even more natural gas generating capacity has been added in the Pacific Northwest.

Figure 4 shows CO_2 emissions by fuel type since 1990 for the generation of electricity. Notice the jump in emissions associated with natural gas fired generation during the West

Coast electricity market crisis during the year 2000 and the drought of 2001. The Energy Information Agency has just started disaggregating the use of fuels for electrical generation within the commercial and industrial sectors. Previously, what was reported as natural gas and petroleum consumption within those two sectors included the use of some of those fuels for electrical generation. The break out of fuel used for electric power generation began with the 1990 data set.

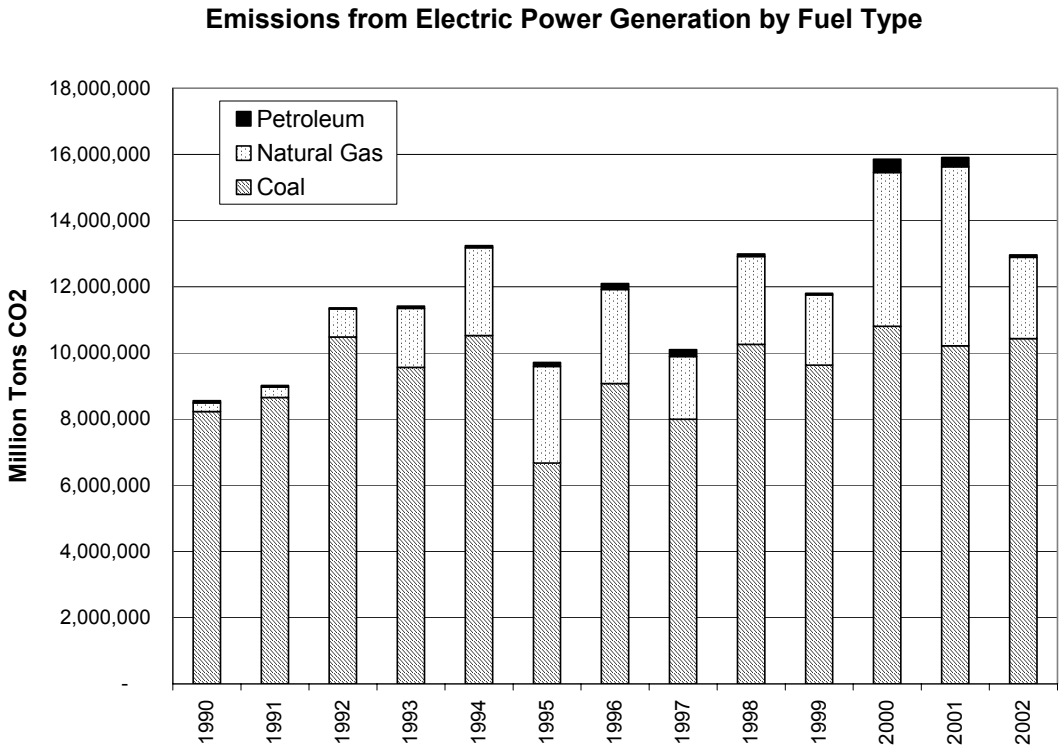

Figure 4. Carbon Dioxide Emissions from Electric Power Generation by Fuel Type

The industrial and buildings sectors (residential and commercial) consume significant quantities of electricity, which is generated by many sources, including fossil fuel fired electrical generating facilities. Figure 5 shows the effect of adding the carbon dioxide emissions associated with electric power generation and use, to the emissions from direct fossil use in the building sector. The CO_2 contribution from electricity is prorated from the total electric power generation emissions and the fraction of electricity sold to the building sector. The emissions contribution from electricity use in the building sector has grown from near zero before 1972 to about 50 percent in 2002.

While the use of electricity in the building sector has increased, the CO_2 emissions per Btu of equivalent electricity are lower than the CO_2 emissions from fossil fuels. This is because the majority of the electricity generated in Washington comes from sources that do not emit carbon dioxide: hydropower and nuclear power. The industrial sector is also a large consumer of electricity, but the impact of including CO_2 emissions associated with fossil fuel fired electric power generation is not as great in this case. Electricity related emissions only accounted for 18 percent of total industrial carbon dioxide emissions in 2001.

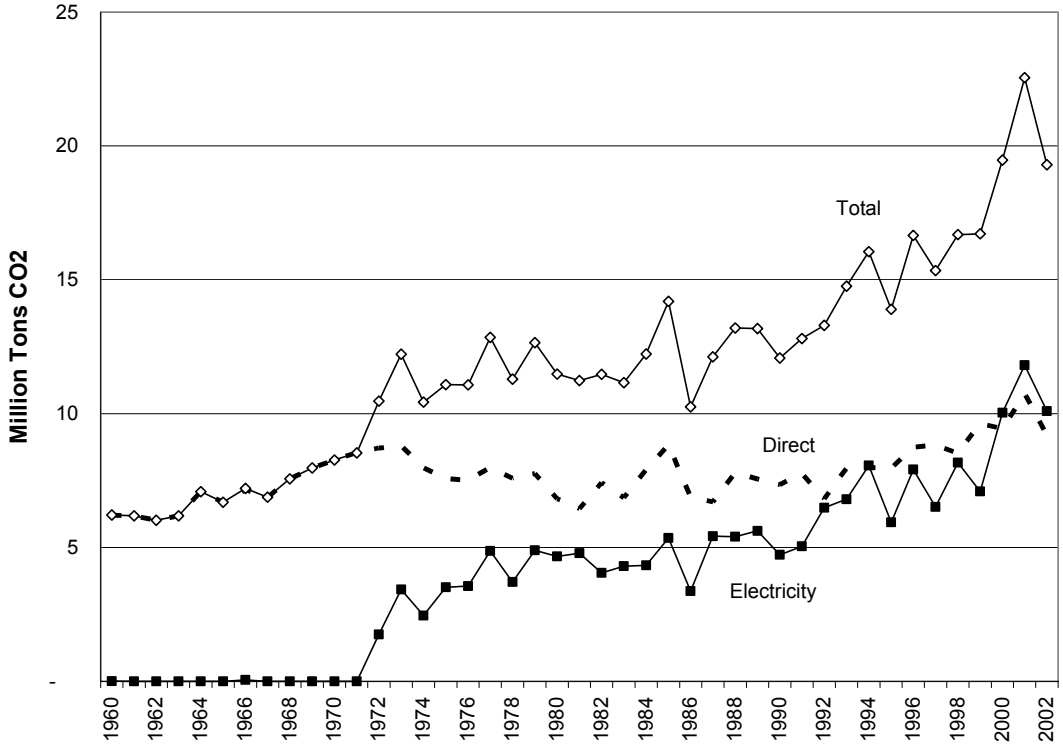

Figure 5. Direct, Electric Power Associated and Total CO_2 Emissions from Building Sector

Figure 6 shows carbon dioxide emissions by end use sector when emissions from electric power production are allocated to the sectors according to their share of electricity. The transportation carbon dioxide emissions change very little because electricity use is a very minor component of this sector. The industrial and particularly the building sectors show the most change because they consume large amounts of electricity.

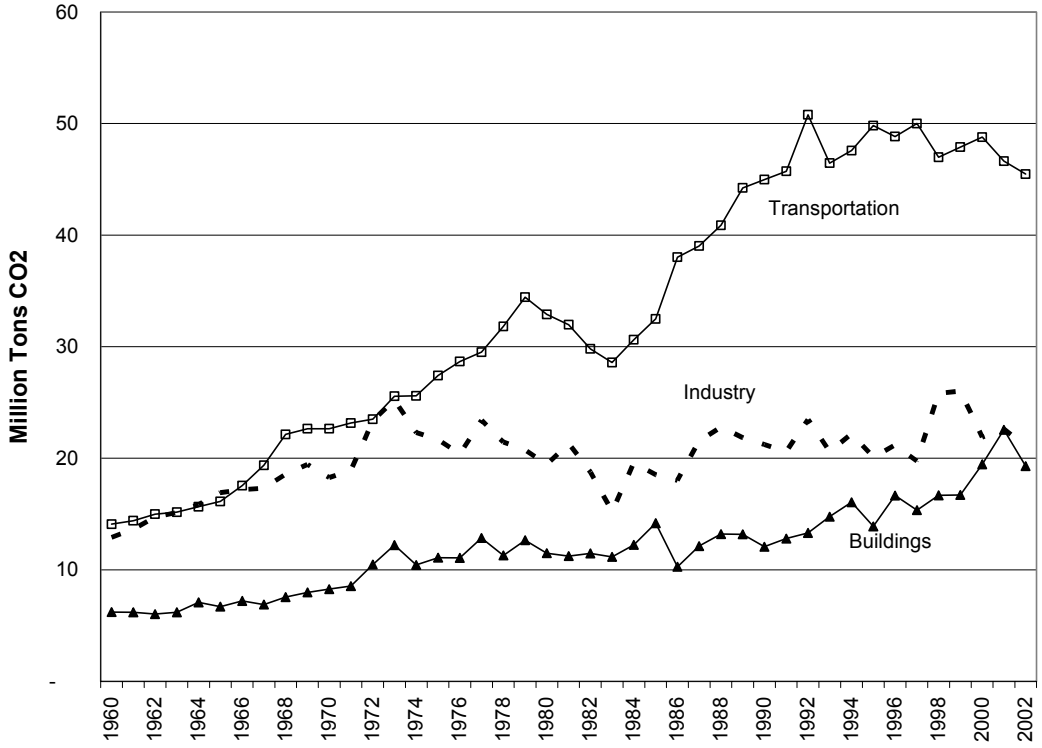

Figure 6. Carbon Dioxide Emissions by Sector with Electricity Related Emissions Allocated

Perspectives

Over the last 40 years there are several trends worth noting as they provide some perspective in determining strategies to mitigate our greenhouse gas emissions. Figure 7 shows the trends for total carbon dioxide emissions, the per capita emissions and emissions per dollar of gross state product ($GSP) from 1977 to 2001. $GSP is expressed in constant 2003 dollars. The values are indexed so that the value in 1977 is equal to 100 (1977 is the first year that $GSP data became available). Over this period, total emissions have increased about 40 percent, the emissions per capita have stayed relatively constant, and the emissions per constant dollar of gross state product have decreased by 45 percent.

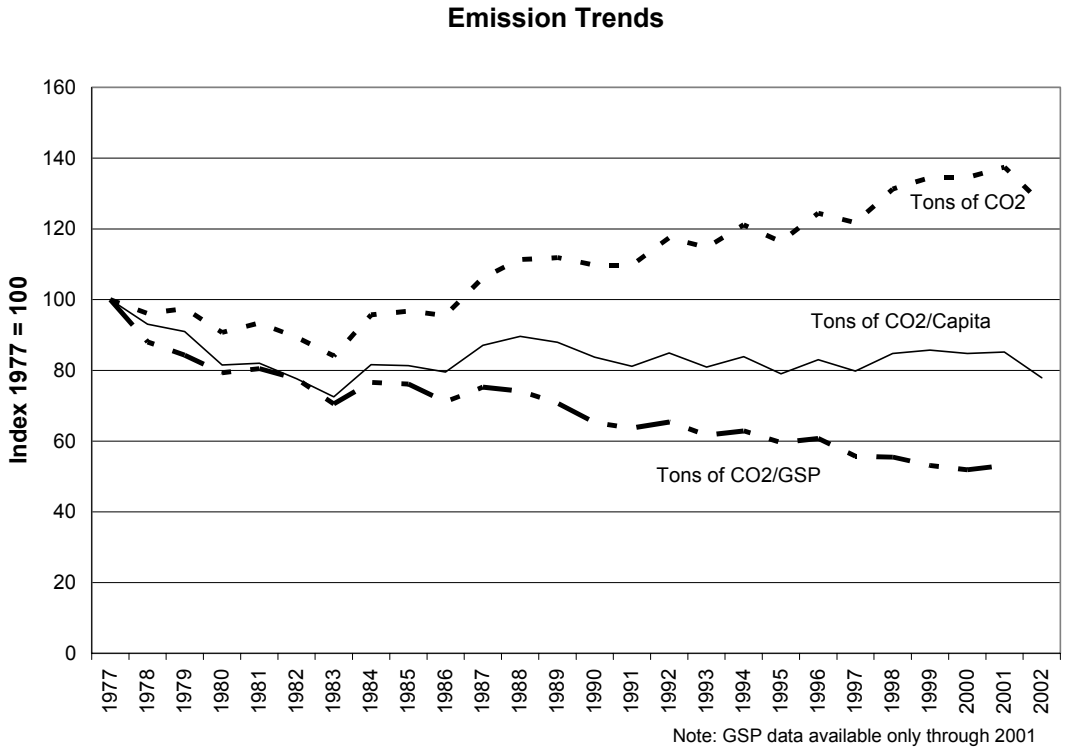

Figure 7. Trends in Emissions, Population, and GSP

A number of factors contributed to the trends shown in Figure 7. First, total emissions after declining in the face of high energy prices and prolonged recession during the late 1970's and early 1980's, have increased slowly since the early 1980s at about 2.3 percent per year. This is roughly equivalent to the state's population growth rate. Second, per capita carbon dioxide emissions remained roughly constant over the past 20 years, despite increasing per capita consumption (house size, vehicle miles traveled, etc.). This is a result of efficiency improvements in direct fuel use and electricity consumption, as well as fuel switching to less carbon intensive fuels. Finally, carbon dioxide emissions per $GSP (expressed as constant 2003 dollars) has declined markedly over the past 25 years. The reasons for this decline include the efficiency improvements and fuel switching factors mentioned above, plus the continuing transformation of our society from a manufacturing based economy to a more services and information-based economy. An example of this continuing transformation is the emergence and growth of the software industry during the 1980s and 1990s. The software industry contributes significantly to GSP, but consumes relatively small amounts of energy, which consequently results in relatively limited carbon dioxide emissions.

The correlation of carbon dioxide emissions with population is also of interest. Figure 8 presents data for energy related emissions and population from 1960 through 2002. The relationship is almost linear and has a correlation coefficient of 90 percent indicating a strong relationship between the growth in population and increased carbon dioxide emissions. Over the 42-year period the trend has been rather consistent. There have been many changes over that period of time as discussed above, including fuel switching,

efficiency improvements, increased use of fossil fuels for electric power generation, and a change to a more service oriented economy. Nevertheless, carbon dioxide emissions have remained strongly correlated with population level.

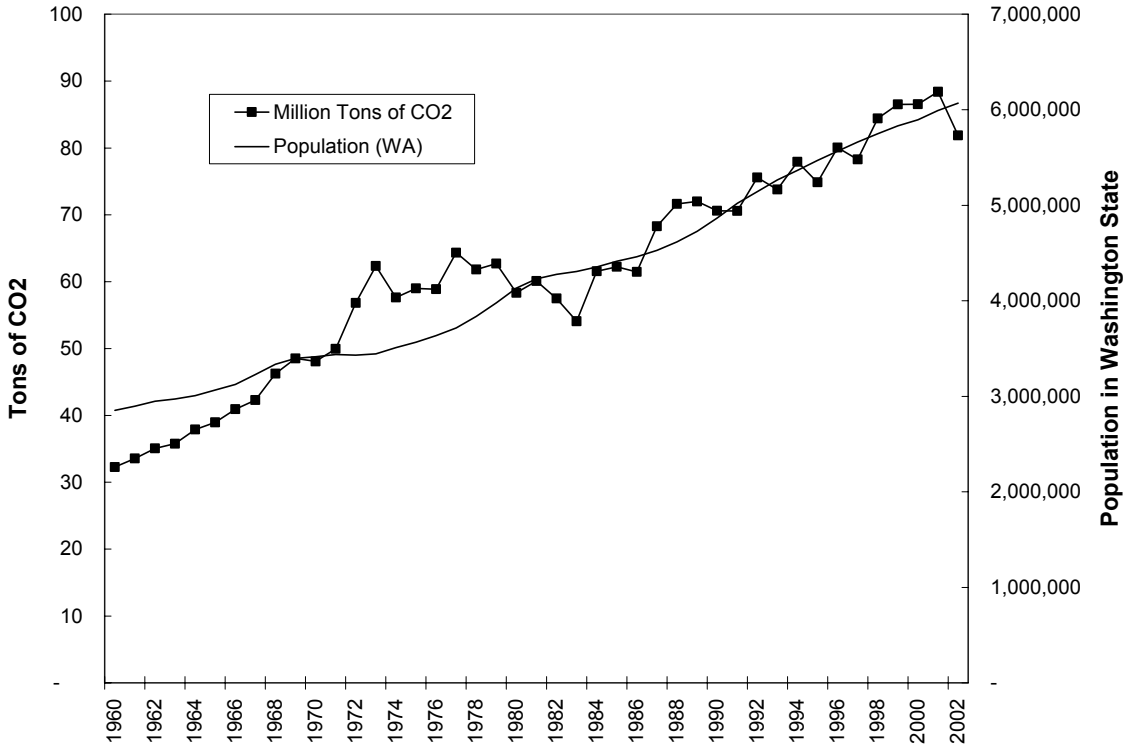

Figure 8. Correlation Between Population and CO_2 Emissions

References

1. Kerstetter, J, *Greenhouse Gas Emissions in Washington State: Sources and Trends, Washington State Community*, Trade and Economic Development, Energy Policy Group, August 1999.
2. The Third Assessment Report is available at http://www.ipcc.ch/pub/reports.htm
3. The State inventory tool is available form Andrea Denny of the Environmental Protection Agency at denny.andrea@epa.gov.
4. *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventory,* IPCC National Greenhouse Gas Inventories Programme, ISBN 4-88788-000-6, 2001.

Appendix A
Select data tables

Data from Figure 1: Greenhouse Emissions by Sector and Gas Type.

Tons CO2-equivelant

	1990	**1995**	**2000**
Energy	80.54 (81%)	86.31 (84%)	92.48 (85%)
Industry	13.39 (13%)	10.83 (10%)	11.16 (10%)
Agriculture	5.57 (6%)	6.17 (6%)	5.68 (5%)
Total	**99.50**	**103.32**	**109.31**
CO2	80.88 (81%)	86.18 (83%)	92.73 (85%)
CH4	7.90 (8%)	7.59 (7%)	8.40 (8%)
N2O	4.00 (4%)	4.54 (4%)	4.03 (4%)
PFC	6.72 (7%)	5.01 (5%)	4.15 (4%)
Total	**99.50**	**103.32**	**109.31**

Data from Figure 4: Emissions from Electric Power Generation by Fuel Type.

Tons CO2

	Coal	**Natural Gas**	**Petroleum**
1990	8,229,842	255,933	66,469
1991	8,653,151	314,956	48,165
1992	10,479,529	851,628	29,511
1993	9,558,848	1,789,657	68,626
1994	10,525,148	2,656,403	65,282
1995	6,671,938	2,921,557	119,257
1996	9,079,528	2,841,553	173,226
1997	7,996,674	1,898,814	208,401
1998	10,263,762	2,646,921	81,676
1999	9,627,925	2,125,678	47,247
2000	10,807,588	4,646,523	397,513
2001	10,221,045	5,400,928	284,205
2002	10,431,187	2,454,162	77,298